NASA GSFC Perspective on Heterogeneous Processing

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Acronym List

C&DH	Command and Data Handling
DSP	Digital Signal Processor
EO-1	Earth Observing 1
FPGA	Field Programmable Gate Array
GPU	Graphics Processing Unit
GSFC	Goddard Space Flight Center
NASA	National Aeronautics and Space Administration
POL	Point Of Load
WMAP	Wilkinson Microwave Anisotropy Probe

Outline

- NASA GSFC Overview
- Onboard Processing Needs
- General Requirements
- Current Onboard Processing Options
- Future Onboard Processing Solutions
- Enabling Heterogeneous Processing
- Summary

About GSFC

- **Since 1959, NASA's first Space Flight Center has been working to better understand our world, the solar system, and the universe**
- **We help answer humanity's BIG QUESTIONS**
- **We TRANSFORM human understanding of Earth and Space.**
- **Nearly 300 successful missions including the World's First Weather Satellite and the Hubble Space Telescope**
- **2006 Nobel Prize in Physics [Big Bang/Cosmic Background]**
- **Hubble Supported 2011 Nobel Prize in Physics**
- **WMAP Team Awarded 2012 Gruber Prize for Cosmology**

A Diverse Mission Portfolio

Humanities Big Questions

–**Goddard focus is on earth and space science, and the research and technology needed to pursue new science.**

Facilities

Onboard Processing Needs

- **Onboard processing needs for NASA missions span many applications and have widely varying performance requirements**
  - **Low power embedded processing for instrument and subsystem control**
  - **Command and data handling (C&DH) functions**
  - **Science instrument data processing**
  - **Autonomous spacecraft control**

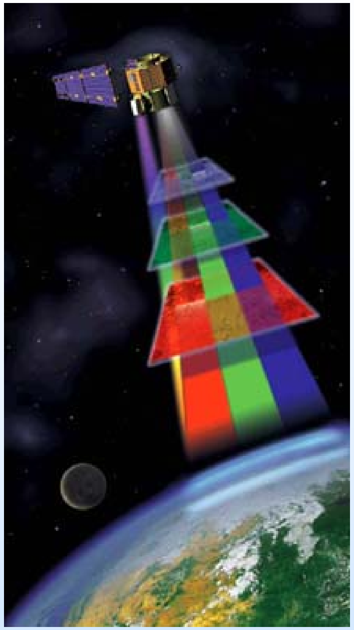
- **Of these, *science instrument data processing* and *autonomous spacecraft control* present the most challenging performance requirements**

Science Instrument Data Processing

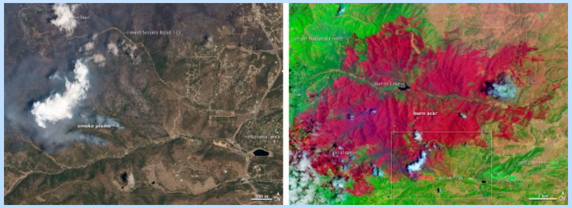
- **For missions where sensor data rates exceed downlink data rates, onboard processing can perform data reduction**
  - **RFI detection within radiometer data**
  - **SAR processing**
  - **Cloud detection for earth imagers**
  - **Classification and selection of hyperspectral data**

- **Onboard processing can also provide low latency data products**
  - **Fire detection in hyperspectral data**
  - **Gamma ray burst location**

- **Close loop instrument control also requires onboard processing**
  - **Adaptive optics**



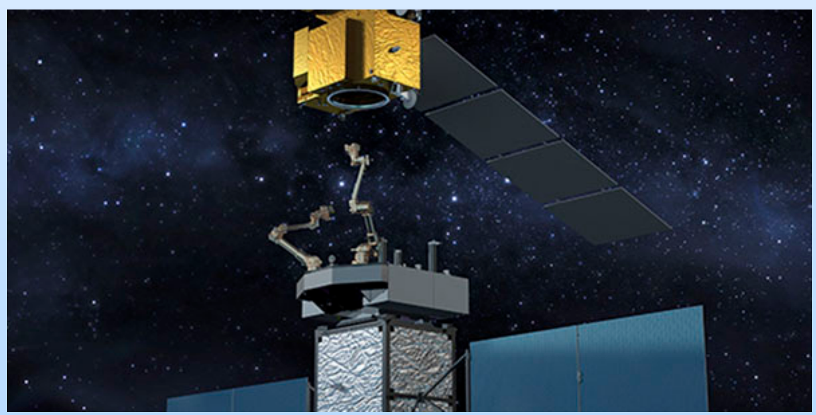
Earth Observing 1 (EO-1) Hyperspectral Imaging Mission



Earth Observing 1 (EO-1) Fire Imagery

Autonomous Spacecraft Control

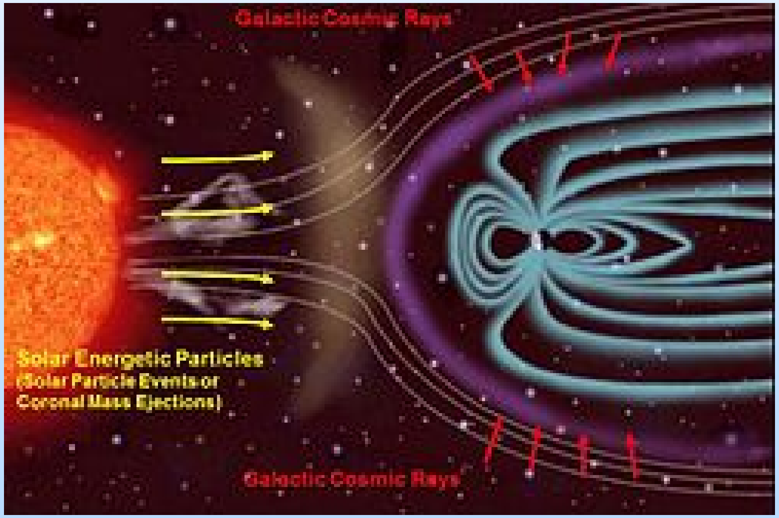
- **Future missions will require increased onboard processing for autonomous spacecraft control functions**
  - **Rendezvous and docking**
  - **Landing**
  - **Diagnostics**
  - **Mission planning**



Restore-L Mission Concept

General Requirements

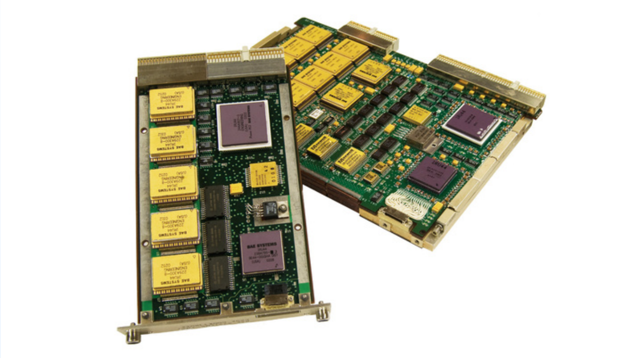
- **While specific requirements vary from mission to mission, several general requirements drive our onboard processing solutions**
  - **Radiation tolerance**
  - **Power efficiency**
  - **Fault tolerance**
  - **Low life cycle cost**
  - **Minimal mission risk**



Space Radiation Environment

Current Onboard Processing Options

- **General Purpose (Single Core) Processors**
  - BAE RAD750 processor
  - Broad Reach BRE440
  - Maxwell SCS750
  - Coldfire



BAE RAD750 Processors

- **FPGA Logic**
  - Xilinx Virtex-5
  - Microsemi RTAX

Xilinx Virtex-5 FPGA

- **Emerging Multi-core Processors**
  - Dual core
  - Quad core

- ***Additional processing performance is needed for our future applications***

Future Onboard Processing Solutions

- **Future processing devices can provide significant advancement beyond the current state of the art**
  - **Next generation multi-core processors**
  - **Coprocessors (DSP, GPU)**
  - **Next generation FPGAs**

- **However, none of these device types is optimal for all processing tasks**

- **Heterogeneous architectures employing multiple processor types (based on mission specific processing needs) are needed to efficiently implement future onboard processing systems**

Enabling Heterogeneous Processing

- Further development is needed to enable heterogeneous processing systems for future missions

- Device “building blocks”
  - Processing devices
  - Memory
  - Onboard networks
  - Point-Of-Load (POL) power converters
  - Printed wiring boards

- Flexible architectures combining these devices to meet mission specific needs
  - Processing requirements and performance
  - Radiation tolerance
  - Fault tolerance
  - Power efficiency
  - Reliability

Enabling Heterogeneous Processing

- Heterogeneous modelling and benchmarking capability
  - Explore processing algorithms
  - Explore mapping to heterogeneous architecture options
  - Assess impact of radiation and fault tolerance techniques

- Application development tools
  - Code portability across multiple processor types
  - Trace and debug across multiple processor types
  - Verification tools for applications distributed across multiple processor types and for radiation and fault mitigation techniques

- Run time tools
  - Dynamic allocation of processing tasks to processing resources
  - Power awareness
  - Fault awareness

Summary

- **Of the many NASA GSFC onboard processing applications, *science instrument data processing* and *autonomous spacecraft control* present the most challenging performance requirements**
- **Several options exist for implementing onboard processing systems, but additional processing performance is needed**
- **Heterogeneous architectures employing multiple processor types (based on mission specific processing needs) are needed to efficiently implement future onboard processing systems**
- **Further development is needed to enable heterogeneous processing systems for future missions**